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Expression cassettes for bidirectional transgenic expression of nucleic acids in plants

The invention relates to expression cassettes and vectors which comprise plant bidirectional promoters, and to the use of these expression cassettes or vectors for transgenic expression of nucleic acid sequences in plant organisms. The invention further relates to transgenic plant organisms transformed with these expression cassettes or vectors, to cultures, parts or propagation material derived therefrom, and to the use of the same for producing human and animal foods, seeds, pharmaceuticals or fine chemicals.

The production of transgenic plants is a fundamental technique of plant biotechnology and thus an indispensable prerequisite for fundamental research on plants, and for producing plants having improved, novel properties for agriculture, for increasing the quality of human foods or for producing particular chemicals or pharmaceuticals. A basic prerequisite for transgenic expression of particular genes in plants is the provision of plant-specific promoters. Various plant promoters are known. The constitutive promoters which are currently predominantly used in plants are almost exclusively viral promoters or promoters isolated from *Agrobacterium* such as, for example, the cauliflower mosaic virus promoter CaMV35S (Odell et al. (1985) Nature 313:810-812). The increasing complexity of the work in plant biotechnology often requires transformation with a plurality of expression constructs. Multiple use of one and the same promoter is problematic especially in plants, because the multiple presence of identical regulatory sequences may result in gene activity being switched off (silencing) (Kumpatla et al. (1998) TIBS 3:97-104; Selker (1999) Cell 97:157-160). There is thus an increasing need for novel promoters. An alternative way of dealing with this problem is the use of so-called "bidirectional" promoters, i.e. regulatory sequences which result in transcription of the upstream and downstream DNA sequences in both direction. It is possible in this case for example for target gene and marker gene to be introduced into a cell under the control of one DNA sequence.

Transgenic expression under the control of bidirectional promoters has scarcely been described to date. The production of bidirectional promoters from polar promoters for expression of nucleic acids in plants by means of fusion with further transcriptional elements has been described (Xie M (2001) Nature Biotech 19: 677-679). The 35S promoter has likewise been converted into a bidirectional promoter (Dong JZ et al. (1991) BIO/TECHNOLOGY 9: 858-863). WO 02/64804 describes the construction of a bidirectional promoter complex based on fusion of enhancer and nuclear promoter elements of various viral (CaMV 35S, CsVMV) and plant (Act2, PRb1b) sequences. US20020108142 describes a regulatory sequence from an intron of the phosphatidylinositol transfer-like protein IV from *Lotus japonicus* (PLP-IV; GenBank Acc. No.: AF367434) and the use thereof as bidirectional promoter. This intron fragment has a transcriptional activity only in the infection zone of the nodules. Other tissues, roots, leaves or flowers show no stain.

Plant promoters permitting bidirectional, ubiquitous (i.e. substantially tissue-nonspecific) and constitutive expression in plants have not been disclosed to date.

WO 03/006660 describes a promoter of a putative ferredoxin gene, and expression constructs, vectors and transgenic plants comprising this promoter. The isolated 836

bp 5'-flanking sequence fused to the glucuronidase gene surprisingly show a constitutive expression pattern in transgenic tobacco. The sequence corresponds to a sequence segment on chromosome 4 of *Arabidopsis thaliana* as deposited in GenBank under the Acc. No. Z97337 (version Z97337.2; base pair 85117 to 85952; the gene starting at bp 85953 is annotated with "strong similarity to ferredoxin [2Fe-2S] I, *Nostoc muscorum*"). The activity detectable in the anthers/pollen of the closed flower buds was only weak, and in mature flowers was zero. Contrary to the prejudice derived from the literature findings against suitability of the promoter for efficient expression of selection markers (for example based on the presumed leaf specificity or the function in photosynthetic electron transport), it was possible to demonstrate highly efficient selection by combination with, for example, the kanamycin resistant gene (*nptII*). WO 03/006660 describes merely the use as "normal" constitutive promoter. Use as bidirectional promoter is not disclosed.

In order to integrate a maximum number of genes into a plant genome via a transfer complex, it is necessary to limit the number and size of regulatory sequences for expressing transgenic nucleic acids. Promoters acting bidirectionally contribute to achieving this object. It is particularly advantageous to use a bidirectional promoter when its activities are present coordinated in the same strength and are located on a short DNA fragment. Since there is little acceptance for the use of viral sequences for expression in transgenic plants, it is advantageous to use regulatory sequences which are likewise from plants.

The object on which the present invention was based was to provide transgenic expression cassettes comprising plant regulatory sequences which mediate bidirectional, ubiquitous and development-independent (constitutive) expression of two nucleic acid sequences which are to be expressed transgenically.

This object is achieved by the present invention. The first aspect of the invention therefore relates to expression cassettes for transgenic expression of two nucleic acid sequences in a plant cell comprising at least one regulatory sequence selected from the group consisting of

- a) the promoter shown in SEQ ID NO: 1 or 2,
- b) functional equivalents of the promoter shown in SEQ ID NO: 1 or 2 which have an identity of at least 80% to the sequence shown in SEQ ID NO: 1 or 2 and which have substantially the same promoter activity as the promoter shown in SEQ ID NO: 1 or 2,
- b) functional equivalents of the promoter shown in SEQ ID NO: 1 or 2 which comprise at least 25 consecutive nucleotides of the sequences shown in SEQ ID NO: 1 or 2 and which have substantially the same promoter activity as the promoter shown in SEQ ID NO: 1 or 2, and
- c) functionally equivalent fragments of sequences a) or b) or c), which have at least 25 consecutive nucleotides of said sequences a) or b) or c) and have substantially the same promoter activity as the promoter shown in SEQ ID NO: 1

or 2,

5 where said regulatory element is disposed between two nucleic acid sequences and is heterogeneous in relation to said nucleic acid sequence and is functionally linked to said nucleic acid sequences in such a way that the expression of two different ribonucleic acid sequences is brought about in at least one plant cell, where said ribonucleic acid sequences are selected from ribonucleic acid sequences coding for

- i) amino acid sequences or
- 10 ii) ribonucleic acid sequences which bring about a reduction in the expression of at least one endogenous gene of said plant cell.

15 The invention further relates to a process for transgenic expression of two ribonucleic acid sequences in plant cells, where an expression cassette comprising at least one regulatory sequence selected from the group consisting of

- a) the promoter shown in SEQ ID NO: 1 or 2,
- 20 b) functional equivalents of the promoter shown in SEQ ID NO: 1 or 2 which have an identity of at least 80% to the sequence shown in SEQ ID NO: 1 or 2 and which have substantially the same promoter activity as the promoter shown in SEQ ID NO: 1 or 2,
- 25 b) functional equivalents of the promoter shown in SEQ ID NO: 1 or 2 which comprise at least 25 consecutive nucleotides of the sequences shown in SEQ ID NO: 1 or 2 and which have substantially the same promoter activity as the promoter shown in SEQ ID NO: 1 or 2, and
- 30 c) functionally equivalent fragments of sequences a) or b) or c), which have at least 25 consecutive nucleotides of said sequences a) or b) or c) and have substantially the same promoter activity as the promoter shown in SEQ ID NO: 1 or 2,

35 is introduced into at least one plant cell,

where said regulatory element is disposed between two nucleic acid sequences and is heterogeneous in relation to said nucleic acid sequence and is functionally linked to said nucleic acid sequences in such a way that the expression of said two different ribonucleic acid sequences is brought about in at least said plant cell, where said
40 ribonucleic acid sequences are selected from ribonucleic acid sequences coding for

- i) amino acid sequences or
- 45 ii) ribonucleic acid sequences which bring about a reduction in the expression of at least one endogenous gene of said plant cell.

The DNA sequence employed in the present invention as bidirectional promoter corresponds to the intergene region between a putative ferredoxin (FD) gene and a putative O-acetylserine lyase (OASTL) gene in *Arabidopsis thaliana*.

It has been possible to achieve particularly good results in plants of the Brassicaceae family such as, for example, arabidopsis or oilseed rape. However, it was also possible to achieve very good results (especially on expression of selection markers) in other plant species (such as, for example, tobacco). The expression "activity" is substantially independent of the nature of the downstream nucleic acid. The use of the bidirectional promoter is suitable both for the expression of selection markers and for any other nucleic acid.

In a preferred embodiment, therefore, the two nucleic acid sequences to be expressed transgenically and comprised in the expression cassettes of the invention, or the ribonucleic acid sequences expressed in the process of the invention, are different. "Different" means in this connection that the ribonucleic acid sequences which are expressed transgenically starting from both sides of the bidirectional promoter differ from one another in at least one base. The two nucleic acid sequences preferably code for different proteins, preferably for proteins differing in function and/or activity.

The invention makes it possible to increase the number of transcription units with a reduced number of promoter sequences. In the case of translation fusions it is also possible to regulate more than two proteins. A particular advantage of this invention is that the expression of these multiple transgenes takes place simultaneously and synchronously under the control of the bidirectional promoter. The promoter is particularly suitable for coordinating expression of nucleic acids. Thus, it is possible to express simultaneously

- i) target protein and selection marker or reporter protein
- ii) selection marker and reporter protein
- ii) two target proteins, e.g. from the same metabolic pathway
- iii) sense and antisense RNA
- iv) various proteins for defense against pathogens

and many more, and bring about improved effects in the plants.

"Expression" comprises the transcription of the nucleic acid sequence which is to be expressed transgenically, but may also - in the case of an open reading frame in the sense orientation - include translation of the transcribed RNA of the nucleic acid sequence which is to be expressed transgenically into a corresponding polypeptide.

"Expression cassette for transgenic expression of nucleic acids or process for transgenic expression of nucleic acids comprises all those constructions or processes brought about by genetic engineering methods, in which either

- a) one of the promoters of the invention (e.g. the promoter shown in SEQ ID NO: 1 or 2 or a functional equivalent thereof), or
- b) the nucleic acid sequence which is to be expressed under the control of said promoter, or
- c) (a) and (b)

- are not in their natural genetic environment (i.e. at their natural chromosomal locus) or have been modified by genetic engineering methods, it being possible for the modification to be for example a substitution, addition, deletion, inversion or insertion of one or more nucleotide residues. In a preferred embodiment, the nucleic acid sequence which is to be expressed under the control of one of the promoters of the invention is heterologous in relation to said promoter, i.e. it is not naturally under the control thereof, but said control has been produced in a non-natural manner (for example by genetic engineering processes).
- 10 The expression cassettes of the invention, vectors derived therefrom or the processes of the invention may comprise functional equivalents to the promoter sequences described in SEQ ID NO: 1 or 2. Functionally equivalent sequences also comprise all the sequences derived from the complementary counterpart strand of the sequences defined by SEQ ID NO: 1 or 2, and have substantially the same promoter activity.
- 15 Functional equivalents in relation to the promoters of the invention means in particular natural or artificial mutations of the promoter sequences described in SEQ ID NO: 1 or 2, and their homologs from other plant genera and species which still have substantially the same promoter activity.
- 20 A promoter activity is referred to as substantially the same if the transcription of a particular gene to be expressed under the control of a particular promoter derived from SEQ ID NO: 1 or 2 under conditions which are otherwise unchanged exhibits a localization within the plant which is at least 50%, preferably at least 70%, particularly preferably at least 90%, very particularly preferably at least 95% coincident with a comparative expression obtained using one of the promoter described by SEQ ID NO: 1 or 2. It is possible in this case for the level of expression to differ both downward and upward from a comparison value. Sequences preferred in this connection are those whose level of expression, measured by means of the transcribed mRNA or the subsequently translated protein, under conditions which are otherwise unchanged, differs quantitatively by not more than 50%, preferably 25%, particularly preferably 10% from a comparison value obtained with a promoter described by SEQ ID NO: 1 or 2. Particularly preferred sequences are those whose level of expression, measured by means of the transcribed mRNA or the subsequently translated protein, under conditions which are otherwise unchanged, exceeds quantitatively by more than 50%, preferably 100%, particularly preferably 500%, very particularly preferably 1000% a comparison value obtained with the promoter described by SEQ ID NO:1. The preferred comparison value is the level of expression of the natural mRNA of the particular gene or of the natural gene product. A further preferred comparison value is the level of expression obtained with any defined nucleic acid sequence, preferably those nucleic acid sequences which code for easily quantifiable proteins. Very particular preference is given in this connection to reporter proteins (Schenborn E & Groskreutz D (1999) Mol Biotechnol 13(1):29-44) such as the "green fluorescence protein" (GFP) (Chui WL et al., Curr Biol 1996, 6:325-330; Leffel SM et al., Biotechniques. 23(5):912-8, 1997), chloramphenicol transferase, a luciferase (Millar et al., Plant Mol Biol Rep 1992 10:324-414) or β -galactosidase, with very particular preference for β -glucuronidase (Jefferson et al. (1987) EMBO J. 6:3901-3907).

Conditions which are otherwise unchanged means that the expression initiated by one of the expression cassettes to be compared is not modified by combination with

additional genetic control sequences, for example enhancer sequences. Unchanged conditions means that all general conditions such as, for example, plant species, stage of plant development, culturing conditions, assay conditions (such as buffer, temperature, substrates etc.) are kept identical between the expressions to be compared.

Mutations comprise substitutions, additions, deletions, inversions or insertions of one or more nucleotide residues. Thus, the present invention also comprises for example nucleic acid sequences which are obtained by modification of a promoter as shown in SEQ ID NO: 1 or 2. The aim of a modification of this type may be further delimitation of the sequence contained therein or, for example, else insertion of further restriction enzyme cleavage sites, deletion of redundant DNA or addition of further sequences, for example further regulatory sequences.

Where insertions, deletions or substitutions such as, for example, transitions and transversions are appropriate, it is possible to use techniques known per se, such as in vitro mutagenesis, primer repair, restriction or ligation. Complementary ends of the fragments can be made available for ligation by manipulations such as, for example, restriction, chewing-back or filling in of protrusions for blunt ends. Analogous results can also be obtained by using the polymerase chain reaction (PCR) using specific oligonucleotide primers.

Identity between two nucleic acids means the identity of the nucleic acid sequence over the entire sequence length in each case, which is calculated by comparison with the aid of the GAP program algorithm (Wisconsin Package Version 10.0, University of Wisconsin, Genetics Computer Group (GCG), Madison, USA), setting the following parameters:

Gap Weight: 12	Length Weight: 4
Average Match: 2,912	Average Mismatch:-2,003

For example, a sequence which has an identity of at least 50% based on nucleic acids with the sequence of SEQ ID NO: 1 means a sequence which has an identity of at least 50% on comparison with the sequence SEQ ID NO: 1 by the above program algorithm with the above set of parameters.

Functional equivalents to the promoter shown in SEQ ID NO: 1 preferably comprises those sequences which have an identity of at least 80%, preferably 90%, particularly preferably at least 95%, very particularly preferably at least 98%, most preferably 99%, to the sequence shown in SEQ ID NO: 1 and additionally exhibits substantially the same promoter activity as the sequence shown in SEQ ID NO: 1.

Functional equivalents to the promoter shown in SEQ ID NO: 2 preferably comprises those sequences which have an identity of at least 80%, preferably 90%, particularly preferably at least 95%, very particularly preferably at least 98%, most preferably 99%, to the sequence shown in SEQ ID NO: 2 and additionally exhibits substantially the same promoter activity as the sequence shown in SEQ ID NO: 2.

Further examples of the promoter sequences employed in the expression cassettes or vectors of the invention can be easily found for example in various organisms whose genomic sequence is known, such as, for example, from *Arabidopsis thaliana*, *Brassica napus*, *Nicotiana tabacum*, *Solanum tuberosum*, *Helianthium annuus*, *Linum sativum* by identity comparisons in data bases.

Process for producing functional equivalents of the invention preferably comprises the introduction of mutations into a promoter shown in SEQ ID NO: 1. A mutagenesis may take place randomly, in which case the mutagenized sequences are subsequently screened for their properties by a trial-by-error procedure. Particularly advantageous selection criteria comprise for example an increased resistance to a selection marker, the level of the resulting expression of the introduced nucleic acid sequence.

In a further embodiment of the invention it is possible for essential regulatory elements of the promoters of the invention to be isolated in a targeted manner and employed as such or in combination with other regulatory elements. Consequently, one aspect of the invention comprises functional equivalents of the promoter shown in SEQ ID NO: 1 or 2 which comprise at least 25, preferably at least 50, particularly preferably at least 100, very particularly preferably at least 200, most preferably at least 400 consecutive nucleotides of the sequences shown in SEQ ID NO: 1 or 2 and have substantially the same promoter activity as the promoter shown in SEQ ID NO: 1 or 2.

Alternatively, nonessential sequences of one of the promoters of the invention can be deleted without significantly impairing the properties mentioned. A further aspect of the invention therefore comprises functionally equivalent fragments of one of the promoter sequences of the invention which have at least 25, preferably at least 50, particularly preferably at least 100, very particularly preferably at least 200, most preferably at least 400 consecutive nucleotides of one of the promoter sequences of the invention and have substantially the same promoter activity as the promoter shown in SEQ ID NO: 1 or 2.

Delimitation of the promoter sequence to particular essential regulatory regions can also be undertaken with the aid of a search routine to search for promoter elements. Frequently, particular promoter elements are present in large numbers in the regions relevant for the promoter activity. This analysis can be undertaken for example using computer programs such as the PLACE program ("Plant Cis-acting Regulatory DNA Elements") (Higo K et al. (1999) *Nucleic Acids Res* 27:1, 297-300) or the BIOBASE database "Transfac" (Biologische Datenbanken GmbH, Braunschweig).

Processes for mutagenizing nucleic acid sequences are known to the skilled worker and include by way of example the use of oligonucleotides having one or more mutations compared with the region to be mutated (e.g. within the framework of a site-specific mutagenesis). Primers having approximately 15 to approximately 75 nucleotides or more are typically employed, with preferably about 10 to about 25 or more nucleotide residues being located on both sides of the sequence to be modified. Details and procedure for said mutagenesis processes are familiar to the skilled worker (Kunkel et al. (1987) *Methods Enzymol* 154:367-382; Tomic et al. (1990) *Nucl Acids Res* 12:1656; Upender et al. (1995) *Biotechniques* 18(1):29-30; US 4,237,224). A mutagenesis can also be achieved by treatment of, for example, vectors comprising

one of the nucleic acid sequences of the invention with mutagenizing agents such as hydroxylamine.

5 The nucleic acid sequences which are present in the expression cassettes of the invention and are to be expressed transgenically may be functionally linked to further genetic control sequences besides one of the promoters of the invention.

10 A functional linkage means for example sequential arrangement of a promoter, of the nucleic acid sequence to be expressed transgenically and, if appropriate, further regulatory elements such as, for example, a terminator in such a way that each of the regulatory elements is able to fulfill its function in the transgenic expression of the nucleic acid sequence, depending on the arrangement of the nucleic acid sequences to give sense or antisense RNA. A direct linkage in the chemical sense is not absolutely necessary for this. Genetic control sequences such as, for example, enhancer
15 sequences are also able to exert their function from remote positions or even from other DNA molecules on the target sequence. Preferred arrangements are those in which the nucleic acid sequence to be expressed transgenically is positioned behind the sequence acting as promoter, so that the two sequences are covalently connected together. In this connection, the distance between the promoter sequence and the
20 nucleic acid sequence to be expressed transgenically is preferably less than 200 base pairs, particularly preferably less than 100 base pairs, very particularly preferably less than 50 base pairs.

25 Production of a functional linkage can be achieved by using conventional recombination and cloning techniques as described for example in Maniatis T et al. (1989) Molecular Cloning: A Laboratory Manual, Cold Spring Harbor Laboratory, Cold Spring Harbor, NY and in Silhavy TJ et al. (1984) Experiments with Gene Fusions, Cold Spring Harbor Laboratory, Cold Spring Harbor, NY and in Ausubel FM et al. (1987) Current Protocols in Molecular Biology, Greene Publishing Assoc. and Wiley
30 Interscience. However, further sequences which have for example the function of a linker with particular restriction enzyme cleavage sites or of a single peptide may also be positioned between the two sequences. Insertion of sequences may also lead to expression of fusion proteins.

35 The term genetic control sequences is to be understood broadly and means all sequences having an influence on the coming into existence of the function of the transgenic expression cassette of the invention. Genetic control sequences modify for example the transcription and translation in prokaryotic or eukaryotic organisms. The expression cassettes of the invention preferably comprise as additional genetic control
40 sequence one of the promoters of the invention 5'-upstream from the particular nucleic acid sequence to be expressed transgenically, and a terminator sequence 3'-downstream, and if appropriate further usual regulatory elements, in each case functionally linked to the nucleic acid sequence to be expressed transgenically.

45 Genetic control sequences also comprise further promoters, promoter elements or minimal promoters which are able to modify the expression-controlling properties. It is thus possible for example through genetic control sequences for tissue-specific expression to take place additionally in dependence on particular stress factors. Corresponding elements are described for example for water stress, abscisic acid

(Lam E and Chua NH, (1991) J Biol Chem 266(26):17131-17135) and heat stress (Schöffl F et al. (1989) Mol Gen Genetics 217(2-3):246-53).

5 A further possibility is for further promoters which make expression possible in further plant tissues or in other organisms such as, for example, *E.coli* bacteria to be functionally linked to the nucleic acid sequence to be expressed. Suitable plant promoters are in principle all the promoters described above. It is conceivable for example that a particular nucleic acid sequence is described by a promoter (for example one of the promoters of the invention) in one plant tissue as sense RNA and
10 translated into the corresponding protein, while the same nucleic acid sequence is transcribed by another promoter with a different specificity in a different tissue into antisense RNA, and the corresponding protein is downregulated. This can be implemented by an expression cassette of the invention by the one promoter being positioned in front of the nucleic acid sequence to be expressed transgenically, and the
15 other promoter behind.

Genetic control sequences further comprise also the 5'-untranslated region, introns or the noncoding 3' region of genes, preferably of the pFD gene and/or of the OASTL gene. It has been shown that untranslated regions may play a significant functions in
20 the regulation of gene expression. Thus, it has been shown that 5'-untranslated sequences may enhance the transient expression of heterologous genes. They may moreover promote tissue specificity (Rouster J et al.(1998) Plant J. 15:435-440.). Conversely, the 5'-untranslated region of the opaque-2 gene suppresses expression. Deletion of the corresponding region leads to an increase in gene activity (Lohmer S et al. (1993) Plant Cell 5:65-73). The nucleic acid sequence indicated under SEQ ID NO:
25 2 comprises the segment of the FD gene and of the OASTL gene which represents the promoter and the 5'-untranslated region up to the ATG start codon of the respective protein. An intron is present in the 5' untranslated region of the OASTL gene, as can be proved by the structure of the cDNA clones. The intron limits are located at 14 bp (3'
30 side of the intron) and 281 bp (5' side of the intron). Base pair numbering corresponding to the numbering of the promoter shown in SEQ ID NO: 2. The intron has a strong expression-promoting function in both directions of transcription. The reason for this might be the existence of an enhancer in this region.

35 In a preferred embodiment, therefore, the bidirectional promoter of the invention is described by the sequence shown in SEQ ID NO: 2 or by sequences which have an identity of at least 80%, preferably at least 90%, particularly preferably at least 95%, very particularly preferably at least 98%, most preferably at least 99% to the sequence shown in SEQ ID NO: 2.

40 Further 5'-untranslated sequences and introns with expression-promoting function are known to the skilled worker. McElroy and coworkers (McElroy et al. (1991) Mol Gen Genet 231(1):150-160) reported on a construct based on the rice actin 1 (Act1) promoter for transforming monocotyledonous plants. Use of the Act1 intron in
45 combination with the 35S promoter in transgenic rice cells led to an expression rate which was increased ten-fold compared with the isolated 35S promoter. Optimization of the sequence environment of the translation initiation site of the reporter gene gene (GUS) resulted in a four-fold increase in GUS expression in transformed rice cells. Combination of the optimized translation initiation site and of the Act1 intron resulted in

a 40-fold increase in GUS expression by the CaMV35S promoter in transformed rice cells; similar results have been obtained with transformed corn cells. Overall, it was concluded from the investigations described above that the expression vectors based on the Act1 promoter are suitable for controlling sufficiently strong and constitutive expression of foreign DNA in transformed cells of monocotyledonous plants.

The expression cassette may comprise one or more so-called enhancer sequences functionally linked to the promoter, which make increased transgenic expression of the nucleic acid sequence possible. It is also possible to insert additional advantageous sequences, such as further regulatory elements or terminators, at the 3' end of the nucleic acid sequences which are to be expressed transgenically. The nucleic acid sequences which are to be expressed transgenically may be present in one or more copies in one of the expression cassettes of the invention.

Control sequences additionally mean those which make homologous recombination or insertion into the genome of a host organism possible or which allow deletion from the genome. It is possible in homologous recombination for example for the natural promoter of a particular gene to be replaced by one of the promoters of the invention. Methods such as the cre/lox technology permit tissue-specific deletion, which is inducible in some circumstances, of the expression cassette from the genome of the host organism (Sauer B. (1998) *Methods*. 14(4):381-92). In this case, particular flanking sequences are attached (lox sequences) to the target gene and subsequently make deletion possible by means of cre recombinase.

The promoter to be introduced can be placed by means of homologous recombination in front of the target gene which is to be expressed transgenically by linking the promoter to DNA sequences which are, for example, homologous to endogenous sequences which precede the reading frame of the target gene. Such sequences are to be regarded as genetic control sequences. After a cell has been transformed with the appropriate DNA construct, the two homologous sequences can interact and thus place the promoter sequence at the desired site in front of the target gene, so that the promoter sequence is now functionally linked to the target gene and forms an expression cassette of the invention. The selection of the homologous sequences determines the promoter insertion site. It is possible in this case for the expression cassette to be generated by homologous recombination by means of single or double reciprocal recombination. In single reciprocal recombination there is use of only a single recombination sequence, and the complete introduced DNA is inserted. In double reciprocal recombination the DNA to be introduced is flanked by two homologous sequences, and the flanking region is inserted. The latter process is suitable for replacing, as described above, the natural promoter of a particular gene by one of the promoters of the invention and thus modifying the location and timing of gene expression. This functional linkage represents an expression cassette of the invention.

To select successfully homologously recombined or else transformed cells it is usually necessary additionally to introduce a selectable marker. Various suitable markers are mentioned below. The selection marker permits selection of transformed from untransformed cells. Homologous recombination is a relatively rare event in higher eukaryotes, especially in plants. Random integrations into the host genome

predominate. One possibility of deleting randomly integrated sequences and thus enriching cell clones having a correct homologous recombination consists of using a sequence-specific recombination system as described in US 6,110,736.

5 Polyadenylation signals suitable as control sequences are plant polyadenylation signals and - preferably - those from *Agrobacterium tumefaciens*. In a particularly preferred embodiment, the expression cassette comprises a terminator sequence which is functional in plants. Terminator sequences which are functional in plants means in general sequences able to bring about termination of transcription of a DNA
10 sequence in plants. Examples of suitable terminator sequences are the OCS (octopine synthase) terminator and the NOS (nopaline synthase) terminator. However, plant terminator sequences are particularly preferred. Plant terminator sequences means in general sequences which are a constituent of a natural plant gene. Particular preference is given in this connection to the terminator of the potato cathepsin D inhibitor gene (GenBank Acc. No.: X74985) or of the terminator of the field bean storage protein gene VfLEIB3 (GenBank Acc. No.: Z26489). These terminators are at
15 least equivalent to the viral or T-DNA terminators described in the art.

The skilled worker is aware of a large number of nucleic acids and proteins whose
20 recombinant expression is advantageous under the control of the expression cassettes or processes of the invention. The skilled worker is further aware of a large number of genes through whose repression or switching off by means of expression of an appropriate antisense RNA it is possible likewise to achieve advantageous effects. Non-restrictive examples of advantageous effects which may be mentioned are:

- 25 - facilitated production of a transgenic organism for example through the expression of selection markers
- achievement of resistance to abiotic stress factors (heat, cold, aridity, increased
30 moisture, environmental toxins, UV radiation)
- achievement of resistance to biotic stress factors (pathogens, viruses, insects and diseases)
- 35 - improvement in human or animal food properties
- improvement in the growth rate of the yield.

Some specific examples of nucleic acids whose expression provides the desired
40 advantageous effects may be mentioned below:

1. selection markers

45 Selection marker comprises both positive selection markers which confer resistance to an antibiotic, herbicide or biocide, and negative selection markers which confer sensitivity to precisely the latter, and markers which provide the transformed organism with a growth advantage (for example through expression of key genes of cytokine biosynthesis; Ebinuma H et al. (2000) Proc Natl Acad Sci USA 94:2117-2121). In the case of positive selection, only the organisms which express the corresponding

selection marker thrive, whereas in the case of negative selection it is precisely these which perish. The use of a positive selection marker is preferred in the production of transgenic plants. It is further preferred to use selection markers which confer growth advantages. Negative selection markers can be used advantageously if the intention is to delete particular genes or genome sections from an organism (for example as part of a crossbreeding process).

The selectable marker introduced with the expression cassette confers resistance to a biocide (for example a herbicide such as phosphinothricin, glyphosate or bromoxynil), a metabolism inhibitor such as 2-deoxyglucose 6-phosphate (WO 98/45456) or an antibiotic such as, for example, kanamycin, G 418, bleomycin, hygromycin, on the successfully recombined or transformed cells. The selection marker permits selection of transformed from transformed from untransformed cells (McCormick et al. (1986) Plant Cell Rep 5:81-84). Particularly preferred selection markers are those which confer resistance to herbicides. The skilled worker is aware of numerous selection markers of this type and the sequences coding therefor. Non-restrictive examples may be mentioned below:

i) positive selection markers:

The selectable marker introduced with the expression cassette confers resistance to a biocide (for example a herbicide such as phosphinothricin, glyphosate or bromoxynil), a metabolism inhibitor such as 2-deoxyglucose 6-phosphate (WO 98/45456) or an antibiotic such as, for example, tetracycline, ampicillin, kanamycin, G 418, neomycin, bleomycin or hygromycin, on the successfully transformed cells. The selection marker permits selection of transformed from untransformed cells (McCormick et al. (1986) Plant Cell Rep 5:81-84). Particularly preferred selection markers are those which confer resistance to herbicides. Examples of selection markers which may be mentioned are:

- DNA sequences which code for phosphinothricin acetyltransferases (PAT; also called bialaphos resistance gene (bar)) and bring about detoxification of the herbicide phosphinothricin (PPT) (de Block et al. (1987) EMBO J 6:2513-2518). Suitable bar genes can be isolated from, for example, *Streptomyces hygrosopicus* or *S. viridochromogenes*. Corresponding sequences are known to the skilled worker (GenBank Acc. No.: X17220, X05822, M22827, X65195; US 5,489,520). Also described are synthetic genes for example for expression in plastids AJ028212. A synthetic Pat gene is described in Becker et al. (1994) Plant J 5:299-307. The genes confer resistance to the herbicide bialaphos and are a widely used marker in transgenic plants (Vickers JE et al. (1996) Plant Mol Biol Rep 14:363-368; Thompson CJ et al. (1987) EMBO J 6:2519-2523).
- 5-enolpyruvylshikimate-3-phosphate synthase genes (EPSP synthase genes) which confer resistance to glyphosate (N-(phosphonomethyl)glycine) (Steinrücken HC et al. (1980) Biochem Biophys Res Commun 94:1207-1212; Levin JG and Sprinson DB (1964) J Biol Chem 239:1142-1150; Cole DJ (1985) Mode of action of glyphosate; A literature analysis, p. 48-74. In: Grossbard E and Atkinson D (eds.). The herbicide glyphosate. Butterworths, Boston.). Glyphosate-tolerant EPSPS

- variants are preferably used as selection markers (Padgett SR et al. (1996). New weed control opportunities: development of soybeans with a Roundup Ready™ gene. In: Herbicide Resistant Crops (Duke SO ed.), pp. 53-84. CRC Press, Boca Raton, FL; Saroha MK und Malik VS (1998) J Plant Biochem Biotechnol 7:65–72).
- 5 The EPSPS gene of the *Agrobacterium* sp. strain CP4 has a natural glyphosate tolerance which can be transferred to appropriate transgenic plants (Padgett SR et al. (1995) Crop Science 35(5):1451–1461). 5-Enolpyruvylshikimate-3-phosphate synthases which are glyphosate-tolerant are described for example in US 5,510,471; US 5,776,760; US 5,864,425; US 5,633,435; US 5,627,061; US 10 5,463,175; EP 0 218 571. Further sequences are described under GenBank Accession X63374. The *aroA* gene is further preferred (M10947).
- the *gox* gene (glyphosate oxide reductase from *Achromobacter* sp.) coding for the glyphosate-degrading enzymes. GOX can confer resistance to glyphosate (Padgett SR et al. (1996) J Nutr. 126(3):702-16; Shah D et al. (1986) Science 233: 478-481).
 - 15 - the *deh* gene (coding for a dehalogenase which inactivates dalapon), (GenBank Acc. No.: AX022822, AX022820 and WO99/27116)
 - 20 - *bxn* genes which code for bromoxynil-degrading nitrilase enzymes. For example the nitrilase from *Klebsiella ozanenae*. Sequences are to be found in GenBank for example under the Acc. No: E01313 and J03196.
 - neomycin phosphotransferases confer resistance to antibiotics (aminoglycosides) such as neomycin, G418, hygromycin, paromomycin or kanamycin by reducing their inhibiting effect through a phosphorylation reaction. The *nptII* gene is particularly preferred. Sequences can be obtained from GenBank (AF080390 minitransposon mTn5-GNm; AF080389 minitransposon mTn5-Nm, complete sequence). In addition, the gene is already a component of numerous expression vectors and can be isolated therefrom by using processes familiar to the skilled worker (such as, for example, polymerase chain reaction) (AF234316 pCAMBIA-2301; AF234315 pCAMBIA-2300, AF234314 pCAMBIA-2201). The NPTII gene codes for an aminoglycoside 3'-O-phosphotransferase from *E. coli*, Tn5 (GenBank Acc. No: U00004 Position 1401-2300; Beck et al. (1982) Gene 19 327-336).
 - 25 30 35 - the *DOG^{R1}* gene. The *DOG^{R1}* gene was isolated from the yeast *Saccharomyces cerevisiae* (EP 0 807 836). It codes for a 2-deoxyglucose-6-phosphate phosphatase which confers resistance to 2-DOG (Randez-Gil et al. 1995, Yeast 11, 1233-1240; Sanz et al. (1994) Yeast 10:1195-1202, sequence : GenBank Acc. No.: NC001140 chromosome VIII, *Saccharomyces cerevisiae* position 194799-194056).
 - 40 45 - sulfonylurea- and imidazolinone-inactivating acetolactate synthases which confer resistance to imidazolinone/sulfonylurea herbicides. Suitable examples are the sequence deposited under GenBank Acc No.: X51514 for the *Arabidopsis thaliana* Csr 1.2 gene (EC 4.1.3.18) (Sathasivan K et al. (1990) Nucleic Acids Res. 18(8):2188). Acetolactate synthases which confer resistance to imidazolinone herbicides are also described under GenBank Acc. No.: AB049823, AF094326, X07645, X07644, A19547, A19546, A19545, I05376, I05373, AL133315.

- 5 - hygromycin phosphotransferases (X74325 *P. pseudomallei* gene for hygromycin phosphotransferase) which confer resistance to the antibiotic hygromycin. The gene is a constituent of numerous expression vectors and can be isolated therefrom by using processes familiar to the skilled worker (such as, for example, polymerase chain reaction) (AF294981 pINDEX4; AF234301 pCAMBIA-1380; AF234300 pCAMBIA-1304; AF234299 pCAMBIA-1303; AF234298 pCAMBIA-1302; AF354046 pCAMBIA-1305.; AF354045 pCAMBIA-1305.1)
- 10 - Resistance genes for

 - a) chloramphenicol (chloramphenicol acetyltransferase),
 - 15 b) tetracycline, various resistance genes are described, e.g. X65876 *S. ordonez* genes class D tetA and tetR for tetracycline resistance and repressor proteins X51366 *Bacillus cereus* plasmid pBC16 tetracycline resistance gene. In addition, the gene is already a constituent of numerous expression vectors and can be isolated therefrom by using processes familiar to the skilled worker (such as, for example, polymerase chain reaction)
 - 20 c) streptomycin, various resistance genes are described, e.g. with the GenBank Acc. No.: AJ278607 *Corynebacterium acetoacidophilum* ant gene for streptomycin adenylyltransferase.
 - 25 d) zeocin, the corresponding resistance gene is a constituent of numerous cloning vectors (e.g. L36849 cloning vector pZEO) and can be isolated therefrom by using processes familiar to the skilled worker (such as, for example, polymerase chain reaction).
 - 30 e) ampicillin (β -lactamase gene; Datta N, Richmond MH. (1966) *Biochem J.* 98(1):204-9; Heffron F et al (1975) *J. Bacteriol* 122: 250-256; the Amp gene was first cloned to prepare the *E. coli* vector pBR322; Bolivar F et al. (1977) *Gene* 2:95-114). The sequence is a constituent of numerous cloning vectors and can be isolated therefrom by using processes familiar to the skilled worker (such as, for example, polymerase chain reaction).
- 35 - Genes such as the isopentenyltransferase from *Agrobacterium tumefaciens* (strain:PO22) (Genbank Acc. No.: AB025109). The *ipt* gene is a key enzyme in cytokine biosynthesis. Overexpression thereof facilitates regeneration of plants (e.g. selection on cytokine-free medium). The process for utilizing the *ipt* gene is described (Ebinuma H et al. (2000) *Proc Natl Acad Sci USA* 94:2117-2121; Ebinuma H et al. (2000) Selection of Marker-free transgenic plants using the onco-

40 genes (*ipt*, *rol* A, B, C) of *Agrobacterium* as selectable markers, In *Molecular Biology of Woody Plants*. Kluwer Academic Publishers).
- 45 Various further positive selection markers which confer a growth advantage on the transformed plants compared with untransformed ones, and processes for their use are described inter alia in EP-A 0 601 092. Examples which should be mentioned are β -glucuronidase (in conjunction with, for example, cytokinin glucuronide), mannose-6-phosphate isomerase (in conjunction with mannose), UDP-galactose 4-epimerase (in

conjunction with, for example, galactose), with particular preference for mannose-6-phosphate isomerase in conjunction with mannose.

ii) Negative selection markers

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Negative selection markers make it possible for example to select organisms with successfully deleted sequences which comprise the marker gene (Koprek T et al. (1999) Plant J 19(6):719-726). In the case of negative selection, for example a compound which otherwise has no disadvantageous effect for the plant is converted into a compound having a disadvantageous effect by the negative selection marker introduced into the plant. Also suitable are genes which per se have a disadvantageous effect, such as, for example, thymidine kinase (TK), diphtheria toxin A fragment (DT-A), the codA gene product coding for a cytosine deaminase (Gleave AP et al. (1999) Plant Mol Biol. 40(2):223-35; Perera RJ et al. (1993) Plant Mol. Biol 23(4): 793-799; Stougaard J (1993) Plant J 3:755-761), the cytochrome P450 gene (Koprek et al. (1999) Plant J 16:719-726), genes coding for a haloalkane dehalogenase (Naested H (1999) Plant J 18:571-576), the iaaH gene (Sundaresan V et al. (1995) Genes & Development 9:1797-1810) or the tms2 gene (Fedoroff NV & Smith DL (1993) Plant J 3:273-289).

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The concentrations used in each case for the selection of antibiotics, herbicides, biocides or toxins must be adapted to the particular test conditions or organisms. Examples which may be mentioned for plants are kanamycin (Km) 50 mg/l, hygromycin B 40 mg/l, phosphinothricin (ppt) 6 mg/l.

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It is also possible to express functional analogs of said nucleic acids coding for selection markers. Functional analogs means in this connection all the sequences which have substantially the same function, i.e. are capable of selecting transformed organisms. It is moreover perfectly possible for the functional analog to differ in other features. It may for example have a higher or lower activity or else possess further functionalities.

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2. Improved protection of the plant against abiotic stress factors such as aridity, heat, or cold for example through overexpression of antifreeze polypeptides from Myoxocephalus Scorpius (WO 00/00512), Myoxocephalus octodecemspinosus, the Arabidopsis thaliana transcription activator CBF1, glutamate dehydrogenases (WO 97/12983, WO 98/11240), calcium-dependent protein kinase genes (WO 98/26045), calcineurins (WO 99/05902), farnesyltransferases (WO 99/06580), Pei ZM et al., Science 1998, 282: 287-290), ferritin (Deak M et al., Nature Biotechnology 1999, 17:192-196), oxalate oxidase (WO 99/04013; Dunwell JM Biotechnology and Genetic Engineering Reviews 1998, 15:1-32), DREB1A factor (dehydration response element B 1A; Kasuga M et al., Nature Biotechnology 1999, 17:276-286), genes of mannitol or trehalose synthesis such as trehalose-phosphate synthase or trehalose-phosphate phosphatase (WO 97/42326), or by inhibition of genes such as of trehalase (WO 97/50561). Particularly preferred nucleic acids are those coding for the transcriptional activator CBF1 from Arabidopsis thaliana (GenBank Acc. No.: U77378) of the antifreeze protein from Myoxocephalus octodecemspinosus (GenBank Acc. No.: AF306348) or functional equivalents thereof.

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3. Expression of metabolic enzymes for use in the animal and human food sectors, for example expression of phytase and cellulases. Particular preference is given to nucleic acids such as the artificial cDNA coding for a microbial phytase (GenBank Acc. No.: A19451) or functional equivalents thereof.
4. Achievement of resistance for example to fungi, insects, nematodes and diseases through targeted secretion or accumulation of particular metabolites or proteins in the epidermis of the embryo. Examples which may be mentioned are glucosinolates (defense against herbivores), chitinases or glucanases and other enzymes which destroy the cell wall of parasites, ribosome-inactivating proteins (RIPs) and other proteins of the plants' resistance and stress responses, as are induced on injury or microbial attack of plants or chemically by, for example, salicylic acid, jasmonic acid or ethylene, lysozymes from non-plant sources such as, for example, T4 lysozyme or lysozyme from various mammals, insecticidal proteins such as *Bacillus thuringiensis* endotoxin, α -amylase inhibitor or protease inhibitors (cowpea trypsin inhibitor), glucanases, lectins such as phytohemagglutinin, wheatgerm agglutinin, RNases or ribozymes. Particularly preferred nucleic acids are those coding for the chit42 endochitinase from *Trichoderma harzianum* (GenBank Acc. No.: S78423) or for the N-hydroxylating, multifunctional cytochrome P-450 (CYP79) proteins from *Sorghum bicolor* (GenBank Acc. No.: U32624) or functional equivalents thereof.
5. The accumulation of glucosinolates in plants of the Cardales genus, especially the oil seeds to protect from pests (Rask L et al. (2000) Plant Mol Biol 42:93-113; Menard R et al. (1999) Phytochemistry 52:29-35), expression of the *Bacillus thuringiensis* endotoxin under the control of the 35S CaMV promoter (Vaeck et al. (1987) Nature 328:33-37) or protection of tobacco against fungal attack by expression of a bean chitonase under the control of the CaMV promoter (Broglie et al. (1991) Science 254:1194-119, is known.

The expression of synthetic cryIA(b) and cryIA(c) genes which code for the lepidoptera-specific delta endotoxins from *Bacillus thuringiensis* can bring about resistance to insect pests in various plants. Thus, it is possible in rice to achieve resistance to two of the principal rice pests, the striped stem borer (*Chilo suppressalis*) and the yellow stem borer (*Scirpophaga incertulas*) (Cheng X et al. (1998) Proc Natl Acad Sci USA 95(6):2767-2772; Nayak P et al. (1997) Proc Natl Acad Sci USA 94(6):2111-2116).
5. Expression of genes which bring about accumulation of fine chemicals such as of tocopherols, tocotrienols or carotenoids. An example which may be mentioned is phytoene desaturase. Nucleic acids which code for the phytoene desaturase from *Narcissus pseudonarcissus* (GenBank Acc. No.: X78815) or functional equivalents thereof are preferred.
6. Production of nutraceuticals such as, for example, polyunsaturated fatty acids such as, for example, arachidonic acid or EP (eicosapentaenoic acid) or DHA (docosahexaenoic acid) by expression of fatty acid elongases and/or desaturases or production of proteins having an improved nutritional value such

as, for example, having a high content of essential amino acids (e.g. the methionine-rich 2S albumin gene of the Brazil nut). Preferred nucleic acids are those which code for the methionine-rich 2S albumin from *Bertholletia excelsa* (GenBank Acc. No.: AB044391), the $\Delta 6$ -acyllipid desaturase from *Physcomitrella patens* (GenBank Acc. No.: AJ222980; Girke et al. (1998) *Plant J* 15:39-48), the $\Delta 6$ -desaturase from *Mortierella alpina* (Sakuradani et al. (1999) *Gene* 238:445-453), the $\Delta 5$ -desaturase from *Caenorhabditis elegans* (Michaelson et al. 1998, *FEBS Letters* 439:215-218), the $\Delta 5$ -fatty acid desaturase (des-5) from *Caenorhabditis elegans* (GenBank Acc. No.: AF078796), the $\Delta 5$ -desaturase from *Mortierella alpina* (Michaelson et al. *J Biol Chem* 273:19055-19059), the $\Delta 6$ -elongase from *Caenorhabditis elegans* (Beaudoin et al. (2000) *Proc Natl. Acad Sci USA* 97:6421-6426), the $\Delta 6$ -elongase from *Physcomitrella patens* (Zank et al. (2000) *Biochemical Society Transactions* 28:654-657) or functional equivalents thereof.

7. Production of fine chemicals (such as, for example, enzymes) and pharmaceuticals (such as, for example, antibodies or vaccines as described in Hood EE, Jilka JM. (1999) *Curr Opin Biotechnol.* 10(4):382-6; Ma JK, Vine ND (1999) *Curr Top Microbiol Immunol* 236:275-92). It has been possible for example to produce recombinant avidin from chicken egg white and bacterial β -glucuronidase (GUS) on a large scale in transgenic corn plants (Hood et al. (1999) *Adv Exp Med Biol* 464:127-47). These recombinant proteins from corn plants are marketed as high-purity biochemicals by Sigma Chemicals Co.

8. Achieving an increased storage ability in cells which normally comprise few storage proteins or lipids with the aim of increasing the yield of these substances, for example by expression of an acetyl-CoA carboxylase. Preferred nucleic acids are those which code for the acetyl-CoA carboxylase (accase) from *Medicago sativa* (GenBank Acc. No.: L25042) or functional equivalents thereof.

Further examples of advantageous genes are mentioned for example in Dunwell JM (2000) *J Exp Bot.* 51 Spec No:487-96.

It is also possible to express functional analogs of said nucleic acids and proteins. Functional analogs means in this connection all the sequences which have substantially the same function, i.e. are capable of the function (for example a substrate conversion or signal transduction) like the protein mentioned by way of example too. It is moreover perfectly possible for the functional analog to differ in other features. It may for example have a higher or lower activity or else possess further functionalities. Functional analogs also means sequences which code for fusion proteins consisting of one of the preferred proteins and other proteins, for example a further preferred protein or else a signal peptide sequence.

Expression of the nucleic acids under the control of the promoters of the invention is possible in any desired cell compartment such as, for example, the endomembrane system, the vacuole and the chloroplasts. Desired glycosylation reactions, especially foldings and the like, are possible by utilizing the secretory pathway. Secretion of the target protein to the cell surface or secretion into the culture medium, for example on use of suspension-cultured cells or protoplasts, is also possible. The target sequences

necessary for this purpose can thus be taken into account in individual vector variations and be introduced, together with the target gene to be cloned, into the vector through use of a suitable cloning strategy. It is possible to utilize as target sequences both gene-intrinsic, where present, or heterologous sequences. Additional heterologous sequences which are preferred for the functional linkage, but not restricted thereto, are further targeting sequences to ensure the subcellular localization in apoplasts, in the vacuole, in plastids, in the mitochondrion, in the endoplasmic reticulum (ER), in the cell nucleus, in elaioplasts or other compartments; and translation enhancers such as the 5' leader sequence from tobacco mosaic virus (Gallie et al. (1987) Nucl Acids Res 15:8693-8711) and the like. The process for transporting proteins which are not localized per se in the plastids in a targeted fashion into the plastids is described (Klosgen RB & Weil JH (1991) Mol Gen Genet 225(2):297-304; Van Breusegem F et al. (1998) Plant Mol Biol 38(3):491-496). Preferred sequences are

- a) small subunit (SSU) of the ribulose-bisphosphate carboxylase (Rubisco ssu) from pea, corn, sunflower
- b) transit peptides derived from genes of plant fatty acid biosynthesis such as the transit peptide of the plastidic acyl carrier protein (ACP), the stearyl-ACP desaturase, β -ketoacyl-ACP synthase or the acyl-ACP thioesterase
- c) the transit peptide for GBSSI (starch granule bound starch synthase I)
- d) LHCP II genes.

The target sequences may be linked to other target sequences which differ from the transit peptide-encoding sequences in order to ensure a subcellular localization in the apoplast, in the vacuole, in plastids, in the mitochondrion, in the endoplasmic reticulum (ER), in the cell nucleus, in elaioplasts or other compartments. It is also possible to employ translation enhancers such as the 5' leader sequence from tobacco mosaic virus (Gallie et al. (1987) Nucl Acids Res 15:8693-8711) and the like.

The skilled worker is also aware that he need not express the genes described above directly by use of the nucleic acid sequences coding for these genes, or repress them for example by anti-sense. He can also use for example artificial transcription factors of the type of zinc finger proteins (Beerli RR et al. (2000) Proc Natl Acad Sci USA 97(4):1495-500). These factors bind in the regulatory regions of the endogenous genes which are to be expressed or repressed and result, depending on the design of the factor, in expression or repression of the endogenous gene. Thus, the desired effects can also be achieved by expression of an appropriate zinc finger transcription factor under the control of one of the promoters of the invention.

The expression cassettes of the invention can likewise be employed for suppressing or reducing replication or/and translation of target genes by gene silencing.

The expression cassettes of the invention can also be employed for expressing nucleic acids which mediate so-called antisense effects and are thus able for example to reduce the expression of a target protein.

Preferred genes and proteins whose suppression is the condition for an advantageous phenotype comprise by way of example, but non-restrictively:

- 5 a) polygalacturonase to prevent cell degradation and mushiness of plants and fruits, tomatoes for example. Preferably used for this purpose are nucleic acid sequences such as that of the tomato polygalacturonase gene (GenBank Acc. No.: X14074) or its homologs from other genera and species.
- 10 b) reduction in the expression of allergenic proteins as described for example in Tada Y et al. (1996) FEBS Lett 391(3):341-345 or Nakamura R (1996) Biosci Biotechnol Biochem 60(8):1215-1221.
- 15 c) changing the color of flowers by suppression of the expression of enzymes of anthocyan biosynthesis. Corresponding procedures are described (for example in Forkmann G, Martens S. (2001) Curr Opin Biotechnol 12(2):155-160). Preferably used for this purpose are nucleic acid sequences like that of flavonoid 3'-hydroxylase (GenBank Acc. No.: AB045593), of dihydroflavanol 4-reductase (GenBank Acc. No.: AF017451), of chalcone isomerase (GenBank Acc. No.: AF276302), of chalcone synthase (GenBank Acc. No.: AB061022), of flavanone 3-beta-hydroxylase (GenBank Acc. No.: X72592) or of flavone synthase II (GenBank Acc. No.: AB045592) or their homologs from other genera and species.
- 20 d) shifting the amylose/amylopectin content in starch by suppression of branching enzyme Q, which is responsible for α -1,6-glycosidic linkage. Corresponding procedures are described (for example in Schwall GP et al. (2000) Nat Biotechnol 18(5):551-554). Preferably used for this purpose are nucleic acid sequences like that of the starch branching enzyme II of potato (GenBank Acc. No.: AR123356; US 6,169,226) or its homologs from other genera and species.
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An "antisense" nucleic acid means primarily a nucleic acid sequence which is wholly or partly complementary to at least part of the sense strand of said target protein. The skilled worker is aware that he can use alternatively the cDNA or the corresponding gene as starting template for corresponding antisense constructs. The antisense nucleic acid is preferably complementary to the coding region of the target protein or a part thereof. The antisense nucleic acid may, however, also be complementary to the non-coding region of a part thereof. Starting from the sequence information for a target protein, an antisense nucleic acid can be designed in a manner familiar to the skilled worker by taking account of the base-pair rules of Watson and Crick. An antisense nucleic acid may be complementary to the whole or a part of the nucleic acid sequence of a target protein. In a preferred embodiment, the antisense nucleic acid is an oligonucleotide with a length of for example 15, 20, 25, 30, 35, 40, 45 or 50 nucleotides.

45 The antisense nucleic acid comprises in a preferred embodiment α -anomeric nucleic acid molecules. α -Anomeric nucleic acid molecules form in particular double-stranded hybrids with complementary RNA in which the strands run parallel to one another, in contrast to the normal β units (Gaultier et al. (1987) Nucleic Acids Res 15:6625-6641).

The use of the sequences described above in sense orientation is likewise encompassed and may, as is familiar to the skilled worker, lead to cosuppression. The expression of sense RNA to an endogenous gene may reduce or switch off its expression, similar to that described for antisense approaches (Goring et al. (1991) Proc Natl Acad Sci USA 88:1770-1774; Smith et al. (1990) Mol Gen Genet 224:447-481; Napoli et al. (1990) Plant Cell 2:279-289; Van der Krol et al. (1990) Plant Cell 2:291-299). It is moreover for the introduced construct to represent the gene to be reduced wholly or only in part. The possibility of translation is unnecessary.

- 10 It is also very particularly preferred to use processes such as gene regulation by means of double-stranded RNA (double-stranded RNA interference). Corresponding processes are known to the skilled worker and described in detail (e.g. Matzke MA et al. (2000) Plant Mol Biol 43:401-415; Fire A. et al (1998) Nature 391:806-811; WO 99/32619; WO 99/53050; WO 00/68374; WO 00/44914; WO 00/44895; WO 00/49035; 15 WO 00/63364). Express reference is made to the processes and methods described in the indicated references. Highly efficient suppression of native genes is brought about here through simultaneous introduction of strand and complementary strand.

- It is possible and advantageous to couple the antisense strategy with a ribozyme process. Ribozymes are catalytically active RNA sequences which, coupled to the 20 antisense sequences, catalytically cleave the target sequences (Tanner NK. FEMS Microbiol Rev. 1999; 23 (3):257-75). This may increase the efficiency of an antisense strategy. Expression of ribozymes for reducing particular proteins is known to the skilled worker and described for example in EP-A1 0 291 533, EP-A1 0 321 201 and 25 EP-A1 0 360 257. Suitable target sequences and ribozymes can be determined as described by Steinecke (Ribozymes, Methods in Cell Biology 50, Galbraith et al. eds. Academic Press, Inc. (1995), 449-460) by secondary structure calculations of ribozyme RNA and target RNA and by the interaction thereof (Bayley CC et al., Plant Mol Biol. 1992; 18(2):353-361; Lloyd AM and Davis RW et al., Mol Gen Genet. 1994 30 Mar; 242(6):653-657). Examples which should be mentioned are hammerhead ribozymes (Haselhoff and Gerlach (1988) Nature 334:585-591). Preferred ribozymes are based on derivatives of the tetrahymena L-19 IVS RNA (US 4,987,071; US 5,116,742). Further ribozymes having selectivity for an L119 mRNA can be selected (Bartel D and Szostak JW (1993) Science 261:1411-1418).

- 35 In a further embodiment, target protein expression can be reduced by using nucleic acid sequences which are complementary to regulatory elements of the target protein genes, form with the latter a triple helical structure and thus prevent gene transcription (Helene C (1991) Anticancer Drug Des. 6(6):569-84; Helene C et al. (1992) Ann NY 40 Acad Sci 660:27-36; Maher LJ (1992) Bioassays 14(12):807-815).

- The bidirectional promoters of the invention are particularly advantageous when it is employed for regulating two enzymes of a metabolic pathway. 2'-Methyl-6-phytylhydroquinone methyltransferase and homogentisate phytyl-pyrophosphate-transferase, for example, can be expressed simultaneously via one of the bidirectional 45 promoters of the invention, bringing about an increase in tocopherols. In addition, inhibition of homogentisate dioxygenase (for example by expression of a corresponding dsRNA) and overexpression of tyrosine aminotransferase leads to an increase in the tocopherol content. In carotenoid metabolism, inhibition of ϵ -cyclase and

overexpression of β -cyclase leads to a change in the content of α -carotene and β -carotene.

5 It is possible to prevent post-transcriptional silencing effects by parallel inhibition of the transcription of the SDE3 gene and overexpression of the recombinant protein (WO 02/063039).

10 Immunologically active parts of antibodies can also be advantageously expressed by using the promoters of the invention. Thus, for example, the heavy chain of an IgG1 antibody can be expressed in one direction, and the light chain in the other direction. The two form a functional antibody after translation (WO 02/101006).

15 A further possibility is to express simultaneously stress-related ion transporters (WO 03/057899) together with herbicide genes in order to increase the tolerance of environmental effects.

20 Many enzymes consist of two or more subunits, both of which are necessary for functioning. It is possible by means of one of the bidirectional promoters of the invention to express two subunits simultaneously. One example thereof is overexpression of the α and β subunits of follicle stimulating human hormone.

25 A construct consisting of a gene for a selection marker and a reporter gene is particularly valuable for establishing transformation systems, when they are regulated by this bidirectional promoter.

30 The expression cassettes of the invention and the vectors derived therefrom may comprise further functional elements. The term functional element is to be understood broadly and means all elements which have an influence on production, multiplication or function of the expression cassettes of the invention or vectors or organisms derived therefrom. Non-restrictive examples which may be mentioned are:

a) Reporter genes

35 Reporter genes or proteins code for easily quantifiable proteins and ensure via an intrinsic color or enzymic activity an assessment of transformation efficiency or of the site or time of expression (Schenborn E, Groskreutz D (1999) Mol Biotechnol 13(1):29-44). Examples which should be mentioned are:

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- green fluorescence protein (GFP) (Chui WL et al., Curr Biol 1996, 6:325-330; Leffel SM et al., Biotechniques. 23(5):912-8, 1997; Sheen et al.(1995) Plant Journal 8(5):777-784; Haseloff et al.(1997) Proc Natl Acad Sci USA 94(6):2122-2127; Reichel et al.(1996) Proc Natl Acad Sci USA 93(12):5888-5893; Tian et al. (1997) Plant Cell Rep 16:267-271; WO 97/41228).

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 - chloramphenicol transferase (Fromm et al. (1985) Proc Natl Acad Sci USA 82:5824-5828),
 - luciferase (Millar et al. (1992) Plant Mol Biol Rep 10:324-414; Ow et al. (1986) Science, 234:856-859); permits detection of bioluminescence.

- β -galactosidase, codes for an enzyme for which various chromogenic substrates are available.
- 5 - β -glucuronidase (GUS) (Jefferson et al. (1987) EMBO J 6:3901-3907) or the uidA gene which encodes an enzyme for various chromogenic substrates.
- 10 - R-locus gene product protein which regulates the production of anthocyanin pigments (red coloration) in plant tissues and thus makes direct analysis possible of the promoter activity without adding additional auxiliaries or chromogenic substrates (Dellaporta et al., In: Chromosome Structure and Function: Impact of New Concepts, 18th Stadler Genetics Symposium 11:263-282, 1988).
- 15 - β -lactamase (Sutcliffe (1978) Proc Natl Acad Sci USA 75:3737-3741), enzyme for various chromogenic substrates (e.g. PADAC, a chromogenic cephalosporin).
- 20 - xylE gene product (Zukowsky et al. (1983) Proc Natl Acad Sci USA 80:1101-1105), catechol dioxygenase, which can convert chromogenic catechols.
- 25 - α -amylase (Ikuta et al. (1990) Bio/Technol. 8:241-242).
- 30 - tyrosinase (Katz et al.(1983) J Gen Microbiol 129:2703-2714), enzyme which oxidizes tyrosine to DOPA and dopaquinone which subsequently form the easily detectable melanin.
- 35 - aequorin (Prasher et al. (1985) Biochem Biophys Res Commun 126(3):1259-1268), can be used in calcium-sensitive bioluminescence detection.
- 40 b) Origins of replication which ensure a multiplication of the expression cassettes or vectors of the invention in, for example, E. coli. Examples which may be mentioned are ORI (origin of DNA replication), the pBR322 ori or the P15A ori (Sambrook et al.: Molecular Cloning. A Laboratory Manual, 2nd ed. Cold Spring Harbor Laboratory Press, Cold Spring Harbor, NY, 1989).
- 45 c) Elements for example "border sequences" which make agrobacteria-mediated transfer into plant cells possible for transfer and integration into the plant genome, such as, for example, the right or left border of the T-DNA or the vir region.
- 45 d) Multiple cloning regions (MCS) permit and facilitate the insertion of one or more nucleic acid sequences.

The skilled worker is aware of various ways of obtaining an expression cassette of the invention. The production of an expression cassette of the invention takes place for example by fusing one of the promoters of the invention (or a functional equivalent or

functionally equivalent part as shown in SEQ ID NO: 1 or 2 or a functional equivalent with a nucleic acid sequence to be expressed, if appropriate with a sequence coding for a transit peptide, preferably a chloroplast-specific transit peptide which is preferably disposed between the promoter and the respective nucleic acid sequence, and with a terminator or polyadenylation signal. Conventional techniques of recombination and cloning are used for this purpose (as described above).

However, and expression cassette also means constructions in which the promoter, without previously having been functionally linked to a nucleic acid sequence to be expressed, is introduced into a host genome, for example via a targeted homologous recombination or a random insertion, there assumes regulatory control of nucleic acid sequences which are then functionally linked to it, and controls transgenic expression thereof. Insertion of the promoter - for example by homologous recombination - in front of a nucleic acid coding for a particular polypeptide results in an expression cassette of the invention which controls the expression of the particular polypeptide in the plant. The insertion of the promoter may also take place by expression of antisense RNA to the nucleic acid coding for a particular polypeptide. Expression of the particular polypeptide in plants is thus downregulated or switched off.

It is also possible analogously for a nucleic acid sequence to be expressed transgenically to be placed, for example by homologous recombination, behind the endogenous, natural promoter, resulting in an expression cassette of the invention which controls the expression of the nucleic acid sequence to be expressed transgenically.

Vectors comprising the expression cassettes described above are also according to the invention. Vectors may be for example plasmids, cosmids, phages, viruses or else agrobacteria.

Another aspect of the invention relates to transgenic organisms transformed with at least one expression cassette of the invention or one vector of the invention, and cells, cell cultures, tissues, parts - such as, for example, leaves, roots etc. of plant organisms - or propagation material derived from such organisms.

Organism, initial or host organisms mean prokaryotic or eukaryotic organisms such as, for example, microorganisms or plant organisms. Preferred microorganisms are bacteria, yeasts, algae or fungi.

Preferred bacteria are bacteria of the genus *Escherichia*, *Erwinia*, *Agrobacterium*, *Flavobacterium*, *Alcaligenes* or cyanobacteria for example of the genus *Synechocystis*. Particularly preferred microorganisms are those able to infect plants and thus to transfer the cassettes of the invention. Preferred microorganisms are those from the genus *Agrobacterium* and in particular of the species *Agrobacterium tumefaciens*.

Preferred yeasts are *Candida*, *Saccharomyces*, *Hansenula* or *Pichia*. Preferred fungi are *Aspergillus*, *Trichoderma*, *Ashbya*, *Neurospora*, *Fusarium*, *Beauveria* or further fungi described in Indian Chem Engr. Section B. Vol 37, No. 1,2 (1995) on page 15, table 6.

- Host or initial organisms preferred as transgenic organisms are in particular plants. Included for the purposes of the invention are all genera and species of higher and lower plants of the plant kingdom. Also included are mature plants, seeds, shoots and seedlings, and parts derived therefrom, propagation material and cultures, for example
5. cell cultures. Mature plants means plants at any stage of development beyond the seedling. Seedling means a young, immature plant in an early stage of development.

- Annual, perennial, monocotyledonous and dicotyledonous plants are preferred host organisms for producing transgenic plants. Plants of the following plant families are preferred:
10. Amaranthaceae, Asteraceae, Brassicaceae, Carophyllaceae, Chenopodiaceae, Compositae, Cruciferae, Cucurbitaceae, Labiatae, Leguminosae, Papilionoideae, Liliaceae, Linaceae, Malvaceae, Rosaceae, Rubiaceae, Saxifragaceae, Scrophulariaceae, Solanaceae, Sterculiaceae, Tetragoniaceae, Theaceae, Umbelliferae.

15. Preferred monocotyledonous plants are in particular cited from the monocotyledonous crop plants such as, for example, of the Gramineae family, such as rice, corn, wheat or other cereal species such as barley, millet, rye, triticale or oats, and sugarcane and all grass species.

20. Preferred dicotyledonous plants are in particular selected from the dicotyledonous crop plants such as, for example,

- Asteraceae such as sunflower, tagetes or calendula and many others,
- 25. - Compositae, especially of the genus Lactuca, very especially of the species sativa (lettuce) and many others,
- Cruciferae, especially the genus Brassica, very especially the species napus (oilseed rape), campestris (beet), oleracea cv Tastie (cabbage), oleracea cv Snowball Y (cauliflower) and oleracea cv Emperor (broccoli) and other brassica species; and of the genus Arabidopsis, very especially the species thaliana and many others,
- 30. - Cucurbitaceae such as melon, pumpkin or zucchini and many others,
- Leguminosae, especially the genus Glycine, very especially the species max (soybean), soybean and alfalfa, pea, beans or peanut and many others
- 40. - Rubiaceae, preferably of the subclass Lamiidae such as, for example, Coffea arabica or Coffea liberica (coffee bush) and many others,
- Solanaceae, especially the genus Lycopersicon, very especially the species esculentum (tomato) and the genus Solanum, very especially the species tuberosum (potato) and melongena (aubergine), and tobacco or paprika and many others,
- 45. - Sterculiaceae, preferably of the subclass Dilleniidae such as, for example, Theobroma cacao (cocoa plant) and many others,

- Theaceae, preferably of the subclass Dilleniidae such as, for example, *Camellia sinensis* or *Thea sinensis* (tea bush) and many others,
- 5 - Umbelliferae, especially the genus *Daucus* (very especially the species *carota* (carrot) and *Apium* (very especially the species *graveolens dulce* (celeriac) and many others; and the genus *Capsicum*, very especially the species *annuum* (pepper) and many others,
- 10 and flax, soybean, cotton, hemp (flax), cucumber, spinach, carrot, sugarbeet and the various tree, nut and vine species, especially banana and kiwi fruit.

Preference is given to *Nicotiana tabacum*, *Tagetes erecta* und *Calendula officinalis*, and all genera and species used as human or animal foods, such as the described
 15 cereals species, or are suitable for the production of oils, such as oilseeds (such as rape), nut species, soybean, sunflower, pumpkin and peanut.

Most preference is given to all plants of the Brassicaceae family, very especially the Brassica species such as *Brassica napus* (oilseed rape), *campestris* (beet), *oleracea*
 20 cv *Tastie* (cabbage), *oleracea* cv *Snowball Y* (cauliflower) and *oleracea* cv *Emperor* (broccoli) and further brassica species; and of the genus *Arabidopsis*, very especially the species *thaliana*.

Plant organisms for the purposes of the invention are additionally further
 25 photosynthetically active capable organisms such as, for example, algae or cyano bacteria, and mosses. Preferred algae are green algae such as, for example, algae of the genus *Haematococcus*, *Phaedactylum tricornutum*, *Volvox* or *Dunaliella*. Particular preference is given to algae such as Chlorophyceae, Phaeophyceae, Rhodophyceae, Myxophyceae, Xanthophyceae, Bacillariophyceae (diatoms) and Euglenophyceae.

30 Production of a transformed organism or of a transformed cell requires introduction of the appropriate DNA into the appropriate host cell. A large number of methods is available for this process, which is referred to as transformation (see also Keown et al. (1990) *Methods in Enzymology* 185:527-537). Thus, for example, the DNA can be
 35 introduced directly by microinjection or by bombardment with DNA-coated microparticles. The cell can also be permeabilized chemically, for example with polyethylene glycol, so that the DNA can enter the cell by diffusion. The DNA can also take place by protoplast fusion with other DNA-containing units such as minicells, cells, lysosomes or liposomes. Electroporation is a further method suitable for introducing
 40 DNA, in which the cells are reversibly permeabilized by an electric pulse.

In the case of plants, the described methods for transformation and regeneration of plants from plant tissues or plant cells are used for transient or stable transformation. Suitable methods are in particular protoplast transformation by polyethylene glycol-
 45 induced DNA uptake, the biolistic process using a gene gun, the so-called particle bombardment method, electroporation, incubation of dry embryos in DNA-containing solution and microinjection.

Besides these "direct" transformation techniques, it is also possible to carry out a transformation by bacterial infection with *Agrobacterium tumefaciens* or *Agrobacterium rhizogenes*. These strains comprise a plasmid (Ti or Ri plasmid) which is transferred to the plant after agrobacterium infection. Part of this plasmid, called T-DNA (transferred DNA), is integrated into the genome of the plant cell.

Agrobacterium-mediated transformation is most suitable for dicotyledonous, diploid plant cells, whereas direct transformation techniques are suitable for every cell type.

Introduction of an expression cassette of the invention into cells, preferably into plant cells, can advantageously be achieved by use of vectors.

In an advantageous embodiment, the introduction of the expression cassette is achieved by means of plasmid vectors. Preferred vectors are those making stable integration of the expression cassette into the host genome possible.

In the case of injection or electroporation of DNA into plant cells, no special requirements must be met by the plasmid used. Simple plasmid such as those of the pUC series can be used. If complete plants are to be regenerated from the transformed cells, it is necessary for an additional selectable marker gene to be present on the plasmid.

Transformation techniques are described for various monocotyledonous and dicotyledonous plant organisms. In addition, various possible plasmid vectors are available for introducing foreign genes into plants, which ordinarily comprise an origin of replication for replication in *E. coli* and a marker gene for selection of transformed bacteria. Examples are pBR322, pUC series, M13mp series, pACYC184 etc.

The expression cassette can be introduced into the vector via a suitable restriction cleavage site. The resulting plasmid is first introduced into *E. coli*. Correctly transformed *E. coli* are selected and cultured, and the recombinant plasmid is isolated by methods familiar to the skilled worker. Restriction analysis and sequencing can be used to check the cloning step.

Transformed cells, i.e. those which comprise the introduced DNA integrated into the DNA of the host cell, can be selected from untransformed ones if a selectable marker is a constituent of the introduced DNA. Any gene that is able to confer a resistance to antibiotics or herbicides can act for example as marker. Transformed cells expressing such as marker gene are able to survive in the presence of concentrations of an appropriate antibiotic or herbicide which kill an untransformed wild type. An example are the bar gene that confers resistance to the herbicide phosphinothricin (Rathore KS et al., *Plant Mol Biol.* 1993 Mar; 21(5):871-884), the nptII gene that confers resistance to kanamycin, the hpt gene which confers resistance to hygromycin, or the EPSP gene which confers resistance to the herbicide glyphosate.

Depending on the method for DNA introduction, further genes may be necessary on the vector plasmid. If agrobacteria are used, the expression cassette is to be integrated into special plasmids, either into an intermediate vector (or shuttle vector) or a binary vector. If, for example, a Ti or Ri plasmid is to be used at least the right border, but in

most cases the right and the left border of the Ti or Ri plasmid T-DNA is connected as flanking region to the expression cassette to be introduced. Binary vectors are preferably used. Binary vectors can replicate both in *E. coli* and in *agrobacterium*. They ordinarily comprise a selection marker gene and a linker or polylinker flanked by the right and left T-DNA border sequence. They can be transformed directly into *agrobacterium* (Holsters et al. (1978) *Mol. Gen. Genet.* 163:181-187). The selection marker gene permits selection of transformed *agrobacteria* and is for example the *nptII* gene which confers resistance to kanamycin. The *agrobacterium* acting as host organism in this case should already comprise a plasmid having the *vir* region. This is necessary for transfer of the T-DNA to the plant cell. An *agrobacterium* transformed in this way can be used to transform plant cells.

The use of T-DNA for transformation of plant cells has been intensively investigated and described (EP 120516; Hoekema, In: *The Binary Plant Vector System*, Offsetdrukkerij Kanthers B.V., Alblasserdam, Chapter V; Fraley et al. (1986) *CRC Crit. Rev. Plant. Sci.*, 4:1-46 and An et al. (1985) *EMBO J.* 4:277-287). Various binary vectors are known and some are commercially available such as, for example, pBIN19 (Clontech Laboratories, Inc. U.S.A.).

DNA is transferred into the plant cell by coculturing the plant explants with *Agrobacterium tumefaciens* or *Agrobacterium rhizogenes*. Starting from infected plant material (e.g. parts of leaves, roots or stems, but also protoplasts or suspensions of plant cells), it is possible to regenerate whole plants by use of a suitable medium that may comprise for example antibiotics or biocides for selecting transformed cells. The resulting plants can then be screened for the presence of the introduced DNA, in this case the expression cassette of the invention. As soon as the DNA is integrated into the host genome, the corresponding genotype is usually stable and the corresponding insertion is also found in subsequent generations. The integrated expression cassette usually comprises a selection marker (see above). The selection marker permits selection of transformed from untransformed cells (McCormick et al. (1986) *Plant Cell Rep* 5:81-84). The resulting plants can be grown and crossed in the usual way. Two or more generations should be cultured in order to ensure that genomic integration is stable and inheritable.

Said processes are described for example in B. Jenes et al., *Techniques for Gene Transfer*, in: *Transgenic Plants*, Vol. 1, Engineering and Utilization, edited by Kung SD & Wu R, Academic Press (1993), pp. 128-143 and in Potrykus I (1991) *Annu Rev Plant Physiol Plant Mol Biol* 42:205-225). The construct to be expressed is preferably cloned into a vector which is suitable for transforming *Agrobacterium tumefaciens*, for example pBin19 (Bevan et al. (1984) *Nucl Acids Res* 12:8711f.).

As soon as a transformed plant cell has been produced, a complete plant can be obtained by using processes known to the skilled worker. This entails starting for example from callus cultures. The formation of shoot and root from these still undifferentiated cell masses can be induced in a known manner. The resulting shoots can be planted out and grown.

The effectiveness of the expression of the transgenically expressed nucleic acids can be measured for example *in vitro* by shoot meristem propagation using one of the selection methods described above.

- 5 Also according to the invention are cells, cell cultures, parts – such as, for example, roots, leaves etc. in the case of transgenic plant organisms - and transgenic propagation material such as seeds or fruits, derived from the transgenic organisms described above.
- 10 Genetically modified plants of the invention which can be consumed by humans and animals may also be used as human food or animal food for example directly or after processing in a manner known per se.
- 15 A further aspect of the invention relates to the use of the transgenic organisms of the invention described above and of the cells, cell cultures, parts - such as, for example, roots, leaves etc. in the case of transgenic plant organisms - and transgenic propagation material such as seeds or fruits derived therefrom for producing human or animal foods, pharmaceuticals or fine chemicals.
- 20 Preference is further given to a process for the recombinant production of pharmaceuticals or fine chemicals in host organisms, where a host organism is transformed with one of the expression cassettes or vectors described above, and this expression cassette comprises one or more structural genes which code for the desired fine chemical or catalyze the biosynthesis of the desired fine chemical, the
- 25 transformed host organism is cultured, and the desired fine chemical is isolated from the culture medium. This process is widely applicable to fine chemicals such as enzymes, vitamins, amino acids, sugars, fatty acids, natural and synthetic flavorings, aromatizing substances and colorants. The production of tocopherols and tocotrienols, and of carotenoids is particularly preferred. The culturing of the transformed host
- 30 organisms, and the isolation from the host organisms or from the culture medium takes place by means of processes known to the skilled worker. The production of pharmaceuticals such as, for example, antibodies or vaccines is described in Hood EE, Jilka JM (1999). Curr Opin Biotechnol 10(4):382-6; Ma JK, Vine ND (1999). Curr Top Microbiol Immunol 236:275-92.
- 35

Sequences

1. SEQ ID NO: 1 Bidirectional promoter from *Arabidopsis thaliana*. Intergene region between the putative FD gene and the putative OASTL gene up to in each case the assumed start of transcription.
2. SEQ ID NO: 2 Bidirectional promoter from *Arabidopsis thaliana* including the 5'-untranslated regions of the putative FD gene and of the putative OASTL gene up to in each case the ATG start codon. Compared with the native sequence, the present sequence comprises an additional C at position 4 compared with the native *Arabidopsis* sequence through introduction of a BamHI recognition sequence.
3. SEQ ID NO: 3 Sequence of the plasmid pUH200. The GUS gene is expressed in the direction of the FD gene, and the nptII gene in the direction of the OASTL gene.
4. SEQ ID NO: 4 Sequence of the plasmid pUH201. The GUS gene is expressed in the direction of the OASTL gene, and the nptII gene in the direction of the FD gene.
5. SEQ ID NO: 5 Oligonucleotide primer pFD3
5'-**acggatcc**gagagacagagacgagacaaaa-3'
6. SEQ ID NO: 6 Oligonucleotide primer pFD4 5'-**gcggatcca**agcttcactgcttaaattc-3'

Description of figures

Fig. 1: Diagrammatic representation of the bidirectional unit in the vectors UH200 and UH201. RB: right border of the agrobacterium T-DNA; CATpA: terminator of the cathepsin D inhibitor; nptII: neomycin phosphotransferase II gene (kanamycin resistance gene); FD: intergene region between FD and OASTL gene (+/- indicate the direction of reading of the FD gene); GUS: β -glucuronidase gene; 35SpA: terminator of the 35S CaMV gene; LB: left border of the agrobacterium T-DNA.

Fig. 2: Analysis of the GUS activity in leaves of transgenic oilseed rape plants transformed with UH 200 (orientation of the ferredoxin gene) or UH 201 (orientation of the OASTL gene) compared with wild type (WT) plants. The results of various lines of UH200 or UH201 transformed oilseed rape plants (identified by number of the respective line on the x axis) are shown. The GUS activity is indicated pmol methylumbelliferone (MU)/mg (protein) min.

Examples

General methods:

- 5 Chemical synthesis of oligonucleotides can take place for example in a known manner by the phosphoramidite method (Voet, Voet, 2nd edition, Wiley Press New York, page 896-897). The cloning steps carried out for the purposes of the present invention, such as, for example, restriction cleavages, agarose gel electrophoreses, purification of DNA fragments, transfer of nucleic acids onto nitrocellulose and nylon membranes, linkage of DNA fragments, transformation of *E. coli* cells, culturing of bacteria, replication of phages and sequence analysis of recombinant DNA are carried out as described in Sambrook et al. (1989) Cold Spring Harbor Laboratory Press; ISBN 0-87969-309-6. Recombinant DNA molecules are sequenced by the method of Sanger (Sanger et al. (1977) Proc Natl Acad Sci USA 74:5463-5467) using a laser fluorescence DNA sequencer supplied by ABI.

Example 1: Isolation of DNA from *Arabidopsis thaliana*, tobacco and oilseed rape

- 20 The genomic DNA from *Arabidopsis thaliana*, tobacco and oilseed rape was isolated using the DNeasy plant mini kit from Qiagen Cat. No. 60106 in accordance with the protocol.

Example 2: Transformation of tobacco and oilseed rape

- 25 The transformation of tobacco took place by infection with *Agrobacterium tumefaciens* in accordance with the method developed by Horsch (Horsch et al. (1985) Science 227: 1229-1231). All the constructs used for the transformation were transformed by the freeze/thaw method (repeated thawing and freezing) into *Agrobacterium tumefaciens*. The *Agrobacterium* colonies comprising the desired construct were selected on YEB medium (1% beef extract (Difco), 0.5% casein enzyme hydrolyzate, 0.1% yeast extract (Duchefa), 0.5% sucrose, 2 mM MgSO₄, 1.5% agar) medium with 50 µg/ml kanamycin, 40 µg/ml gentamycin, 100 µg/ml spectinomycin and 25 µg/ml rifampicin.
- 35 Tobacco plants (*Nicotiana tabacum* L. cv. Samsun NN) were transformed by centrifuging 10 ml of an overnight culture of *Agrobacterium tumefaciens* grown under selection, discarding the supernatant, and resuspending the bacteria in the same volume of antibiotic-free medium. Leaf disks from sterile plants (diameter about 1 cm) were bathed in this bacterial solution in a sterile Petri dish. The leaf disks were then laid on MS medium (Murashige and Skoog (1962) Physiol Plant 15:473ff.) with 2% sucrose and 0.8% Bacto agar in Petri dishes. After incubation at 25°C in the dark for 2 days, they were transferred to MS medium with 100 mg/l kanamycin, 500 mg/l Claforan, 1 mg/l benzylaminopurine (BAP), 0.2 mg/l naphthylacetic acid (NAA), 1.6% glucose and 0.8% Bacto agar, and cultivation was continued (16 hours of light/8 hours of darkness). Growing shoots were transferred to hormone-free MS medium with 2% sucrose, 250 mg/l Claforan and 0.8% Bacto agar.

Oilseed rape was transformed by means of petiole transformation by the method of Moloney et al. (Moloney MM et al. (1989) Plant Cell Rep 8:238-242).

Example 3: Investigation of bidirectional expression of the FD promoter

a) PCR isolation of the FD promoter from *Arabidopsis thaliana*

The putative bidirectional promoter was amplified by PCR from genomic *Arabidopsis thaliana* DNA using the primers FD3 and FD4. The nucleotides in bold print for a BamHI site were attached to the primer FD3. A BamHI site was introduced into the primer FD4 by insertion of a C (bold) as difference from the genomic sequence.

Primer FD3: (SEQ ID NO: 5)

5'-**acggatcc**gagagacagagacgagacaaaa-3'

Primer FD4: (SEQ ID NO: 6)

5'-**gcggatcca**agcttcaactgcttaaattc-3'

Reaction mixture:

1 µl of DNA

37 µl of H₂O

5 µl of 10x buffer

1 µl of FD3 primer 10 µM

1 µl of FD4 primer 10 µM

4 µl of dNTP 2.5 mM

1 µl of Pfu turbo DNA polymerase (Stratagene)

PCR conditions:

1 cycle with 5 min at 95°C

25 cycles with 52°C for 1 min, 72°C for 1 min and 95°C for 30 sec

1 cycle with 72°C for 10 min,

subsequent cooling to 4°C until processed further.

b) Construction of the FD:GUS expression cassettes

The PCR product comprising the FD promoter was cleaved with the restriction enzyme BamHI and ligated into the vector pGUSINT37 (SunGene), likewise BamHI cleaved. The undirected cloning resulted in the two plasmids pFD+GUS and pFD-GUS in which the promoter fragment is placed in front of the GUS gene in opposite orientations in each case. The plasmid pFD+GUS comprises the promoter in the direction of transcription of the putative ferredoxin gene, and the plasmid pFD-GUS in the orientation of the annotated O-acetylserine thiol-lyase gene (OASTL, cysteine synthase).

Example 4: Production of vectors for simultaneous analysis of both directions of transcription of the FD promoter

To analyze both directions of expression, the genes of the selection marker NptII and of the reporter glucuronidase were placed under the control of the bidirectional

promoter into constructs. For this purpose, the plasmids pFD+GUS and pFD-GUS were cleaved with EcoRI/Sall and cloned into the vector pS5NptIIcat (derivative of the pSUN vector; WO 02/00900). The resulting plasmids UH200 (SEQ ID NO: 3) comprises the GUS gene under the control of the transcriptional elements acting in the direction of the ferredoxin gene, and the NptII gene under the control of the transcriptional elements acting in the direction OASTL gene. In the plasmid UH201 (SEQ ID NO: 4), the GUS gene is under the control of the OASTL directed factors and the NptII gene is under the control of the elements controlling the ferredoxin gene (see Fig.1). Both constructs were transformed into the agrobacterium strain GV3101[pMP90] and transformed into tobacco and oilseed rape in accordance with the protocols.

Example: 5 Results of the analysis of kanamycin resistance of the transgenic tobacco plants

Selective regeneration of tobacco plantlets took place on 100 mg/l kanamycin. 86% of the explants of the were transformed with the construct UH200 developed plumules. 89% of the cut shoots rooted on kanamycin-containing medium, and all were transgenic according to PCR analyses. 70% of the explants from the transformation experiment with UH201 developed plumules, of which 90% rooted. Once again, PCR analysis revealed that the plantlets comprised the appropriate construct and are thus transgenic. This example shows that both promoter orientations are suitable in the same way for expressing selection markers during selective regeneration of tobacco.

Example 6: Results of the analysis of kanamycin resistance of the transgenic oilseed rape plants

Selective regeneration of the oilseed rape shoots took place on 18 mg/l kanamycin. The transformation efficiency was 11% for the construct UH200 and 10% for UH201. At the same time, the transformation efficiency under the control of the promoter of nopaline synthase was found to be 8%. This example showed that selective regeneration both under the control of the promoter in the OASTL direction (UH200) and the FD direction (UH201) is comparable with the nosP normally used.

Example 7: GUS analysis of the tissue specificity of the bidirectional promoter in the transgenic tobacco and oilseed rape plants.

The two promoter orientations have shown the same tissue specificities, with the exception in pollen, in the transgenic tobacco and oilseed rape plants (table 1). Whereas no activities were found in the pollen in oilseed rape, the tobacco pollen showed a distinct blue coloration and thus promoter activity. GUS expression regulated by both orientations was found predominantly in green tissue. No expression was detectable in roots and petals. GUS activity was detectable even in very early stages of seed development in oilseed rape.

Tissue		A		B	C	D	E	F	G	H	I	J	K	L
		siL	soL											
Tobacco	FD	++	++	-	+	+	++	++	+	+	++	-	+	++
	OASTL	+	+	-	+	+	+	+	+	+	++	-	+	++
Rape	FD	++	++	-	++	nd	+	+	+	+	+	-	+	-

Table 1: Overview of the tissue specificities in tobacco and oilseed rape.

++ high activity

+ lower activity

- no activity; nd: not determined

5 A leaves (siL: sink leaves; soL: source leaves)

B roots

C seeds

D seedling

E stem

10 F flower stalk

G nodes

H bud

I sepals

J petals

15 K anthers

L pollen.

20 The promoter activity during selective regeneration was followed by staining young shoots with X-Gluc. Transgenic shoots showed an intense blue stain. This experiment again showed the same activity of the bidirectional promoter in both orientations.

Example 8: Quantitative GUS analysis of the bidirectional promoter in transgenic tobacco plants

25 For quantitative analysis of the strength of the FD promoter, leaf and seed material from transgenic plants of both constructs were investigated in parallel. The quantitative GUS assay was carried out in accordance with the procedure of Jefferson with MUG and 4-methylumbelliferone as standard. A similar amount of GUS activity was detected in the seeds of the plants of both orientations. Expression was distinctly measurable in
30 leaf material in both directions, but the intensity was less uniform than in seed material.

Example 9: Quantitative GUS analysis of the bidirectional promoter in the transgenic oilseed rape plants

35 Oilseed rape was transformed - as described above - likewise with the constructs UH200 and UH201. Quantitative GUS analysis of leaf material of transgenic oilseed rape plants showed that the two promoter directions showed an identical activity. Fig. 2 shows the values for the individual lines. The level of expression corresponds to the other polar plant promoters.